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TECHNICAL REPORT NO. S 1005

SCHEDULING JOBS ON A COMPUTER

(CURSORY REVIEW OF THE "STATE-OF-THE-ART")

OPERATIONS RESEARCH BRANCH
OPERATIONS IMPROVEMENT DIVISION

May 1969

by Irwin F. Goodman

TACOM

MANAGEMENT AND DATA SYSTEMS DIRECTORATE
U.S. ARMY TANK AUTOMOTIVE COMMAND Warren, Michigan

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ABSTRACT

A cursory review of the state-of-the-art regarding the scheduling of jobs on computers is accomplished based upon a review of visits to ten computer facilities. During each visit the following type of information was gathered:

How, operationally are the jobs scheduled on a day to day basis on the computer?; What sort of mathematical logical theory is currently being used, or contemplated for in the future, for determining optimum sequencing of jobs on the computer?; What is the philosophy of management regarding the scheduling of jobs on the computer?

FOREWORD

The author wishes to acknowledge Mr. Larry Pyles, Operations Research Analyst, for editorial assistance provided during the preparation of this report.

SCHEDULING JOBS ON A COMPUTER

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1. Introduction

An effort has been underway to ascertain the state-of-the-art of scheduling jobs on a computer. Several computer activities were visited. During each visit the following type of information was gathered when available:

a. How, operationally, are the jobs scheduled on a day to day basis on the computers?

b. What sort of mathematical logical theory is currently being used or contemplated for in the future for determining optimum sequencing of jobs on the computer?

c. What is the philosophy of management regarding the scheduling of jobs on the computer?

This effort was accomplished in support of a larger effort involving the development of techniques and methodology for the planning and scheduling of jobs on computers.

Ten computer activities were contacted. Information obtained from them is included in the following discussion. The information from two of the activities was briefly formalized separately and is referred to individually as Firm A or B.

2. Conclusions

Scheduling of jobs on a computer is essentially a manual, non-automatic process, making use of considerable documentation of essential information relevant to the input, output, and programs for each computer job. It usually involves scheduling sheets and some times also a scheduling board. The essential information documented is that type of information that would "fall-out" if a critical path approach were taken with the development of a network representation. Therefore, most of the systems are essentially using a CPM approach for the planning and scheduling of jobs on the computer but it should be emphasized that none of the scheduling operations formally or even informally were using CPM.

Most of the jobs are scheduled on the basis of due-date and when a conflict arose regarding service to a customer, the computer activity attempted to resolve the service problem through negotiation with the parties involved. If this approach did not succeed, then the problem was referred to higher management for decision.

Some of the computer activities visited plan in the next year to three years to implement an automatic scheduling system. All of the activities emphasize the need for an effective operational manual system prior to the implementation of an automatic system. The availability of certain information as discussed and referred to

2. Conclusions (cont...)

in the findings is highly essential to the effective operation of any type of scheduling system, automatic or non-automatic.

3. Objectives of a Computer Scheduling System

The objective of a computer job scheduling procedure are to control and schedule the work and measure the work performance.

a. Establish machine load and resolve scheduling conflicts on a timely basis.

b. Provide a current picture of the work schedule in order to efficiently use the equipment and evaluate the effect of rescheduling.

c. Advise the customer of job status and reduce the number of contacts made by the customer.

4. Summary of Findings

The following computer scheduling system is essentially a summary of the various computer activities visited. It is essentially a synthesis of the scheduling systems used by the various activities contacted.

For any computer service center to process jobs for their "customers" (i.e., people or organizations within the company), each job must first be completely recorded and documented. The recording and documenting procedure is probably the most vital of all concerns in constructing a "scheduling" system. This is how all the information on any job will be maintained, so as to provide a basis from which a decision can be made in scheduling any combination of these jobs within a given time frame. Documentation of these jobs is illustrated by both firms A and B. In each case basically, the same type of information had been collected for each job. Summarizing the firms documentation of jobs, the following seems to be essential elements for every job in the schedule documentation file:

a. "Type" of job (recurring, rerun, etc.)

b. Running time of program

c. Job number

d. Job name

e. Number of "phases" for each job

f. Running time of each phase

g. Dependent phases (phases which must be run before phase in question)

4. Summary of Findings (cont...)

h. Program memory size

i. Reception time (due time-in for "production" jobs usually)

j. Due-out time

With this documentation file for every job that is run on the computer, the scheduler must determine the number and sequence of jobs to be run in a given time frame. The scheduler must have some "horizon" (i.e., forecast period) for which he must schedule. For most of the computer activities this horizon is 24 hours. Given a 24 hour horizon, the scheduler must first know what jobs are, or will have to be ready to run within the next "horizon". This information is obtained primarily from element No. 9 above -- due time-in and also from element No. 7 -- dependent phases.

Once the scheduler has a list of all jobs that are ready for processing he must set priorities on the jobs. These priorities must obey some rule or decision, that is both uniform and consistent. For example, firm A sets two priorities on each job:

First: What "type" of job is it --

(1) Routine Receiving

(2) Rerun

(3) Unscheduled (nonproduction type)

4. Summary of Findings (cont...)

Second: Within A's divisions "Pool Priorities" existed --

(1) ~~Pool~~ Priority #1 - Input and Output, to and from, all jobs

(2) Pool Priority #2 - all others

Another firm, B, sets priorities based on the following criteria:

a. Time of reception

b. Due time-out

c. ~~Program~~ running time

After the priorities have been set, the scheduler must chose a set of jobs to be run within the next 24 hours horizon and then sequence them in the order of processing. This sequence, of course, is based on the priorities which exist in the set of jobs. At firm A, for example, those jobs with priority 1-1 will be run first followed in order by priorities 1-2, 2-1, 2-2, 3-1, 3-2. This order, of course, is based on one processing unit. If two or more computers or multi-processing were available, the order of processing would probably be altered somewhat, but basically the arrangement of jobs would be such that the high priorities are completed first followed by the other priorities in descending order.

5. Findings

5.1 Firm A

Firm A has a procedure for scheduling jobs on the computer which seems to be clear, concise and efficient. The scheduling procedure is divided into three phases.

Phase I: A customer using these facilities must prepare a phase sheet to be sent to the computer center's staging clerk. He audits the form for completeness, resolves incomplete items with the customer and stamps the time of receipt.

The phase sheet is then sent to the Scheduling Area. There a job indicator is prepared. This is a summary of such information as job number, phase relationships to each other and the entire job, computer number, sequence number, requested completion time and running time. An example of this job indicator is given in TAB 1. The phase sheet is filed by the scheduling clerk in the "Advance" Control file by job number within "Ready for Processing Data" sequence.

The panel Controller then selects "tomorrows" jobs from this "Advance" control file and plots "tomorrows" schedule. The following priorities are used by the scheduler for plotting the jobs' sequence.

a. Routine recurring jobs

b. Reruns due to machine, operator, programmer, or input error

5. Findings (cont...)

c. Scheduled jobs - first-in first-out

d. Unscheduled jobs - first-in, first-out.

Any scheduling conflicts in starting times, etc., are resolved with the customer(s) involved.

Phase II: This consists of the scheduler designating the "Pool Priority" for each job (using the advanced phase sheet) when either The 360/30 or 70/15 machine is required.

The Pool Priority characteristics are as follows:

a. P-1: Pool Priority No. 1.

(1) Input to all O/S* jobs

(2) Expedite top priority scheduled or unscheduled stand-alone (360/30 or 70/15) jobs.

(3) Expedite top priority scheduled O/S output.

b. P-2 - Pool Priority No. 2.

(1) Output from scheduled O/S jobs

(2) Scheduled stand-alone (360/30 or 70/15) jobs

(3) Expedite unscheduled O/S output

Phase III: The entire job is submitted for processing thru the staging clerk. He verifies completeness and correctness of program manuals, card decks, carriage tapes, control cards, computer set-up sheets and input data for each job. After matching the control phase sheet with the run copy, the time of receipt is stamped on the job and both the phase sheet and the job are moved to the Scheduling Area - "Waiting for Job Staging" location.

*O/S "operating system" - monitoring/supervising system.

5. Findings (cont...)

The Panel Controller then takes the job and verifies the schedule and then assigns processing sequence numbers to it. The control copy of the Phase Sheet is placed in the "Active" reference file by sequence number, while the job itself along with the run-copy are released to the Tape Pulling area.

Here the record tapes and discs required for the job are recorded, pulled from the vault, and along with the job, are placed on the "Job Staged" counter by System No.

This is where the computer operator and the coordinator commence actual processing of the job on the computer. Processing is done in the following manner:

a. P-1 has top priority, P-2 next and finally unmarked pool work. Within priorities, jobs processed on a first-in, first-out basis using the Control No. and "Requested Completion Time" to establish running sequence.

b. The scheduler makes the determination when P-1 and P-2 exceed capacity and the first-in, first-out rule cannot be applied.

The most important characteristic of this entire procedure is the ranking of the jobs done by use of priorities. A very interesting note is that each job is ranked by at least two sets of priorities. One is based on the program type, such as:

a. Recurring

b. Reruns

5. Findings (cont...)

c. Scheduled

d. Unscheduled

The other is based on a broader scale, such as:

a. Input

b. Top priority (first set-above) stand-alones

c. Output from O/S

d. Low-priority stand-alones (above)

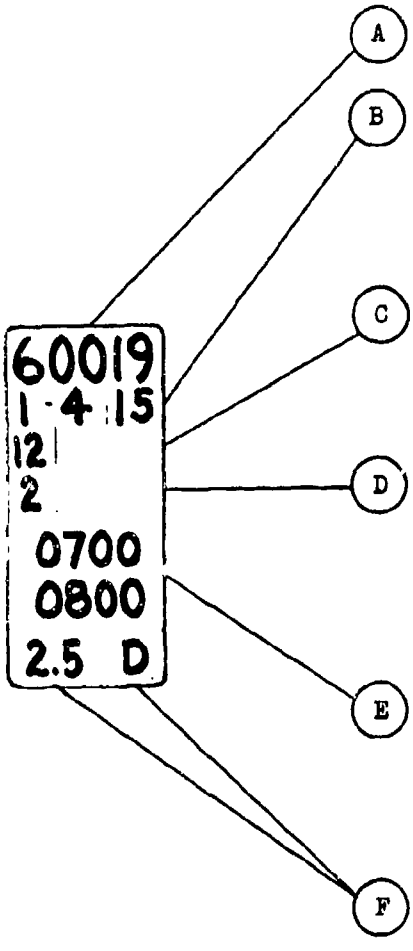
e. Unscheduled O/S output

This means that for given any job the scheduler must determine first what "broad" class it falls into, the "type" of program it is (rerun, etc.), and then based on when it was received and when it must be completed by, he will determine when it can be fit into the schedule.

TAB I

COMPUTER SCHEDULING SYSTEM

Computer Schedule Control Panel - Job Indicator Preparation



A — Enter Job No. as shown on the Phase Sheet

B — Enter left to right, the phase number and its relation to total phases in the job. Consecutively processed phases of the same job on one computer require one Job Indicator be prepared for all phases involved.

C — Enter computer number. Subsequent schedule problems that force a change of computer assignment require the previous computer number be crossed off and the reassigned computer number entered.

D — Enter processing sequence number associated with the assigned computer number. Actual assignment of the sequence number will be deferred until the job is cleared for staging. As scheduling problems develop, a new sequence number will be needed. Cross off previous sequence number and enter reassigned number.

E — Enter the "Ready for Processing" time followed by the "Requested Completion" time as shown on the Phase Sheet. Both times will be entered on the first Job Indicator of a multi-phase job with subsequent Job Indicators requiring only the "Requested Completion" time.

F — Enter the total running time for the Phase(s). To determine running time, increase estimated time for each phase by .1 hr.

Enter on the right, conditional symbols as they apply.

- "D" Indicates Daily job.
- "W" Indicates Weekly or Semi-weekly job.
- "R" Indicates Re-run.
- "U" Indicates Unique Machine Required.
- "X" Indicates Unscheduled job.

5. Findings (cont...)

Firm B

Firm B briefly has a somewhat firm basis for scheduling jobs on their computer. First all "production" jobs to be run on their Burroughs 5500 are completely documented with such things as name, computer run time, CPU run time, type of input and output and how long as well as how much equipment is involved in the input/output phase, frequency of input, earliest start time and required completion time. Furthermore, these production jobs are scheduled on a 24 hour forecast horizon and updated every 5 to 10 minutes. This in turn is reflected on a larger scale by their monthly scheduling board.

With information and controls as exemplified here, a "decision table" is established by which certain jobs can be "scheduled" to run before any others.

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